CHARGING AND DISCHARGING METHODS OF LEAD ACID BATTERY

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ABSTRACT

Battery has played a major in many applications such as electric vehicle and uninterruptable power supply (UPS). Battery becomes a must choice because it can provide immediate power when needed. Among the battery family, lead-acid battery become a popular choice because it came in variety of output voltage and can be recharge. Although the lead-acid can be recharge, problems still occur when recharging the battery. The battery tend to undergo overcharge if the is no control mechanism to stop the charging. This paper represents a method of charging and discharging the battery by using electronic control circuit based on the minimum and maximum voltage battery level. A NI-DAQ 6212 was introduced and configures to connect the electronic control circuit to the personal computer for display and data storage using LabVIEW. A charge and discharge program was developed to use for charging and discharging purpose. The output of this project would be displaying the voltage-time graph as well as the charging and discharging state of the lead-acid battery.

ABSTRAK

Bateri telah memainkan utama dalam banyak aplikasi seperti kenderaan elektrik dan bekalan kuasa uninterruptable (UPS). Bateri menjadi pilihan mesti kerana ia boleh memberikan kuasa serta-merta apabila diperlukan. Antara keluarga bateri, bateri asid-plumbum menjadi pilihan popular kerana ia datang dalam pelbagai voltan keluaran dan boleh caj semula. Walaupun asid plumbum boleh caj semula, masalah masih berlaku apabila mengecas semula bateri. Bateri cenderung untuk menjalani harga yg terlalu mahal jika ada mekanisme kawalan untuk menghentikan pengecasan. Kertas kerja ini merupakan satu kaedah mengecas dan menyahcas bateri dengan menggunakan litar kawalan elektronik yang berdasarkan tahap voltan bateri minimum dan maksimum. A 6212 NI-DAQ telah diperkenalkan dan mengkonfigurasi untuk menyambung litar kawalan electronic untuk komputer peribadi untuk paparan dan penyimpanan data menggunakan LabVIEW. Satu program caj dan pelepasan telah dibangunkan untuk digunakan untuk mengecas dan melaksanakan tujuan. Keluaran projek ini akan memaparkan graf voltan-masa serta keadaan mengecas dan menyahcas bateri asid plumbum.

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LIST OF ABBREVIATIONS

AGM	-	Absorbed Glass Mat
GUI	-	Graphical User Interface
DAQ	-	Data Acquisition
DC	-	Direct Current
USB	-	Universal Serial Bus
NI	-	National Instrument
PC	-	Personal Computer
VRLA	-	Valve Regulated Lead Acid

CHAPTER 1

INTRODUCTION

1.1 Background of Project

Charging and discharging lead-acid battery is an important element to make sure that the battery can still provide power when needed. Charging is process where the energy is being flow into the cell or rechargeable battery by forcing an electrical current through it. Charging a lead acid battery typically have two tasks to accomplish which are to restore the capacity as quickly as possible and to maintain the capacity compensating or self discharge. When a typical lead-acid cell is charged, lead sulphate is converted to lead on the battery's negative plate and lead dioxide on the positive plate. Over-charge reactions begin when the majority of lead sulphate has been converted, typically resulting in the generation of hydrogen and oxygen gas. At moderate charge rates, most of the hydrogen and oxygen will recombine in sealed batteries. In unsealed batteries however, dehydration will occur.

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To maintain capacity on a fully charged battery, a constant voltage is applied. The voltage must be high enough to compensate for self discharge, but not to high as it will cause excessive over-charging. The software that will be use in this project is LabVIEW. The purpose of this software is to monitor and control the voltage so that the control circuit can be switch between charge and discharge mode.

1.2 Problem Statement

There are some problems occur while charging and discharging a battery. The problem is the charging process tends to undergo overcharging because typical lead acid battery does not give signal when it fully charged. To encounter this problem, a new method of charging and discharging technique is used. This method use a software that will cut-off the battery charging and discharging process when the maximum and minimum voltage parameter has been set. There are many types of charging and discharging method use nowadays, each one of them has its own advantages and disadvantages. In this project, the method use is based on the voltage of the lead-acid battery.

1.3 Objectives

The objectives of this project are:

a) To create the charging and discharging program of lead acid battery.

b) To develop an electronic control circuits to control the charge-discharge process.

c) To develop GUI using LabVIEW software, to record, save and monitor the voltage level and charge-discharge state.

d) To experiment the characterization of lead acid battery

1.4 Scope of Project

In this project, a charge-discharge cycle will be created for monitor the lead acid battery voltage level. The electronic control circuit will be developed to control the charge-discharge process. The output from the battery will interface by using DAQ card and monitor from the PC. The output then will be presented in voltage-time graph and charge-discharge state by using the GUI software.

1.5 Chapter Outline

This thesis consists of five chapters including this chapter. The content of each chapter can be outlined as follows:

Chapter 2 provides a literature review, background, previous research done by others researchers in the same area and relevant issues related to the charging and discharging of lead acid battery. This include on overview of battery types use into scope of study. The different types of charging methods are presented to justify the best method that use in the project. Chapter conclusion justifies the need of research on charging and discharging method of lead acid battery.

Chapter 3 describes a broad description of the research methodology in this project. This chapter begins with description of flow chart of the project. The first part of this chapter describes the hardware development. The electric schematic diagram of charge discharge mode with complete relays connection is developed as part of the project. The second part of this chapter describes the programming development that use to control the charge discharge process of lead acid battery. The last part of this chapter is experimental and characterization of lead acid battery. Chapter conclusion summarized the methodology in this study.

Chapter 4 described the result for experimental and characterization of lead acid battery. Result and discussion of the project is presented.

Chapter 5 provides general conclusion based on the project. The limitation of the project is stated and future works for improving the project is highlighted.

CHAPTER 2

LITERATURE REVIEW

2.1 Battery

Battery is a device containing an electric cell or a series of electric cells storing energy that can be converted into electrical power. Battery produces electricity from a chemical reaction [1]. Generally, battery consists of two or more cells connected in series or parallel. A cell consists of a negative electrode; an electrolyte, which conducts ions; a separator, also an ion conductor; and a positive electrode. The electrolyte may be aqueous (composed of water) or non-aqueous (not composed of water), in liquid, paste, or solid form. When the cell is connected to an external load, or device to be powered, the negative electrode supplies a current of electrons that flow through the load and are accepted by the positive electrode. There are two types of battery that commonly use which are primary batteries (disposable battery) and secondary batteries (rechargeable battery).

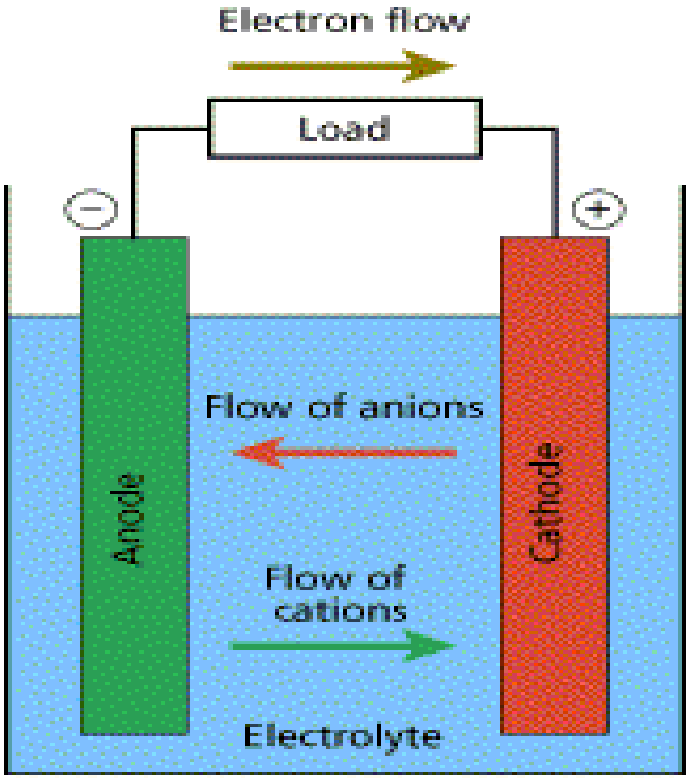

Figure 2.1 Battery operation

2.1.1 Lead Acid Battery

Lead acid battery is the oldest type of rechargeable battery. It is an electrical storage device that uses a reversible chemical reaction to store energy. It uses a combination of lead plates or grids and an electrolyte consisting of a diluted sulphuric acid to convert electrical energy into potential chemical energy and back again. Despite having a very low energy-to-weight ratio and a low energy-to-volume ratio, their ability to supply high surge currents means that the cells maintain a relatively large power-to-weight ratio [2]. In a lead acid cell the active materials are lead dioxide (PbO_2) in the

positive plate, sponge lead (Pb) in the negative plate, and a solution of sulfuric acid (H2SO4) in water as the electrolyte [4]. The chemical reaction during discharge and recharge is normally written:

$$PbO_2 + Pb + 2H_2SO_4 \underset{\text{Charge}}{\overset{\text{Discharge}}{\longrightarrow}} 2PbSO_4 + 2H_20 \qquad \textbf{(2.1)}$$

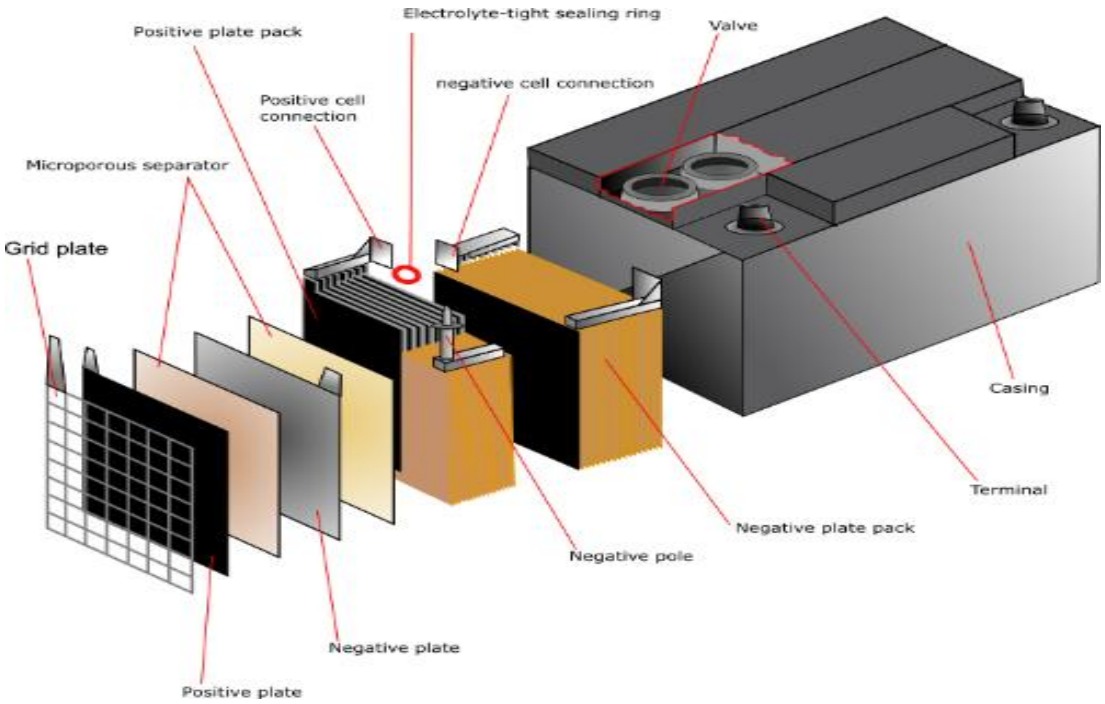

Figure 2.2 Lead acid battery constructions [3]

A lead acid battery is composed of a series of plates immerse in a solution of sulfuric acid. Each plate consists of a grid upon which is attached the active material (lead dioxide on the negative plates, pure lead on the positive plates.) All of the negative plates are connected together, as are all of the positive plates. When the battery is discharged (when it is subjected to an electrical load), acid from the elecrolyte combines with the active plate material. This releases energy and converts the plate material to lead sulfate. The electrolyte become less acidic in the process, and the specific gravity of the solution drops. When a battery is recharged, the opposite occurs: the lead sulfate reverts back to active material, and the electrolyte becomes more acidic with a higher specific gravity. During discharge, the lead dioxide (positive plate) and lead (negative plate) react with the electrolyte of sulfuric acid to create lead sulfate, water and energy. During charging, the cycle is reversed: the lead sulfate and water are electro-chemically converted to lead, lead oxide and sulfuric acid by an external electrical charging source [5].

2.1.2 Valve-Regulated Lead Acid (VRLA) Battery

VRLA battery is a type of lead acid rechargeable battery that commonly known as sealed battery. VRLA battery construction does not require regular addition of water to cells and it vents less gas than flooded lead acid battery. VRLA battery can be used in confine space or poor ventilated spaces because of the venting advantage that result in less gas produce [6]. VRLA batteries are commonly classified as Absorbed Glass Mat (AGM) battery and gel battery (gel cell).

The construction of VRLA is different than flooded lead-acid battery. When the battery is recharged at high voltage, typically greater than 2.30 volts per cell, it will active the pressure relief valve. By releasing the some gas on the battery, it decreased the

overall capacity of the battery. The cell covers typically have gas diffusers built into them that allow safe dispersal of any excess hydrogen that may be formed during overcharge. They are not permanently sealed, but are maintenance free. They can be oriented in any manner, unlike normal lead acid batteries, which must be kept upright to avoid acid spills and to keep the plates' orientation vertical. At high overcharge currents, electrolysis of water occurs, expelling hydrogen and oxygen gas through the battery's valves. Constant-voltage charging is the usual, most efficient and fastest charging method for VRLA batteries, although other methods can be used.[7] VRLA batteries may be continually "float" charged at around 2.35 volts per cell at 25 °C.

2.2 Charging Methods

Charging is a process of supplying direct current to the battery so as to convert it back into chemical state at high energy level, capable of delivering electric power. Charging voltages have a significant effect on battery longevity. Some cells may deteriorate faster than others during operations. Deteriorated cells reduce the output voltage of the battery, and affect the usability and reliability of the circuit [13]. There are varieties of charging methods which can be used to charge sealed lead acid battery. By controlling the charging process, these methods can be classified into some basic categories which are constant-voltage, constant-current, tapered-current and combination charge systems. There are also new methods of charging lead acid battery that use internal voltage control [8] and current pulse or ‘pulse charging’ [9] which will be discussed later.

2.2.1 Constant Current Charging

Constant current charging is a method that is commonly uses for charging lead acid battery. The advantage of using this method is it easy to determine the amount of capacity (amp hrs) supplied during charging process [14]. Besides that, there is no need for temperature compensation which is required in constant voltage systems. Usually, at high-rate of charging, the battery voltage rises excessively and the water decomposes, causing heat generation at the final stage of the charge, thus, damaging the battery. However, the constant current method relatively kept a low rate of charging process and charging time is not critical. The constant current methods may be used as refreshing charge when many batteries is being charge at one time, as this method easily determine the amount of charge returned to the battery. It is not recommended to use constant current charging as refreshing the battery because it will shorten the battery life.

2.2.2 Constant Voltage Charging

Constant voltage charging is a methods use to restore the battery to a fully charge condition in short period of time. This type of charging must has a very stable output voltage and high current capacity, as extremely large currents are allowed to flow in the initial stage of charge, where the battery voltage is low. However, this type of charging method is not practical because the requirement of a high current capacity, results in high cost. The heat generation in the battery is also high because of the high current flow in the battery causing the battery life to be short. Generally, constant voltage charger has a device to limit initial current. This can be accomplished by a constant current regulator, or by designing the overall impedance of the circuit. Constant voltage charger is effectively to charge the battery at short period of time, as during the final stage of

charge, the current automatically decreases and the water decomposition will be minimized.

2.2.3 Tapered Current Charging

Tapered current charging is simple and relatively inexpensive method. This charging method requires circuit with power transformer, rectifiers and a suitable resistance for limiting current. In this method, the charging current drops gradually as the charging proceeds. If the impedance of the circuit is low, a step current slope can be obtained. This type for charge is generally considered to be unsuitable for charging sealed lead acid batteries because the charging current will vary with fluctuation of line voltage as well as changes in battery voltage [10]. These effects, however, can be minimized by using a power transformer with a secondary voltage which is considerably higher than the battery voltage and a suitably high resistance in the circuit for current limiting. This type of charger will perform similar to a constant current charger, and can be utilized instead of a constant current charger for industrial uses; not only for recharging many batteries at one time, but also as a trickle charging system.

2.2.4 Combination Charging (Two-Step)

A combination charging uses two types of charging. It's called a "Two-rate" or "Two-step" charging. A variety of couples can be made, such as constant – current/constant current, constant-voltage/constant-current and so on [10]. In general the first step uses a quick or fast charge mode, and the second uses a low charge current. The switching from the first step to the second can be carried out by many different methods such as battery voltage sensing, a time control, charge current sensing and many more.

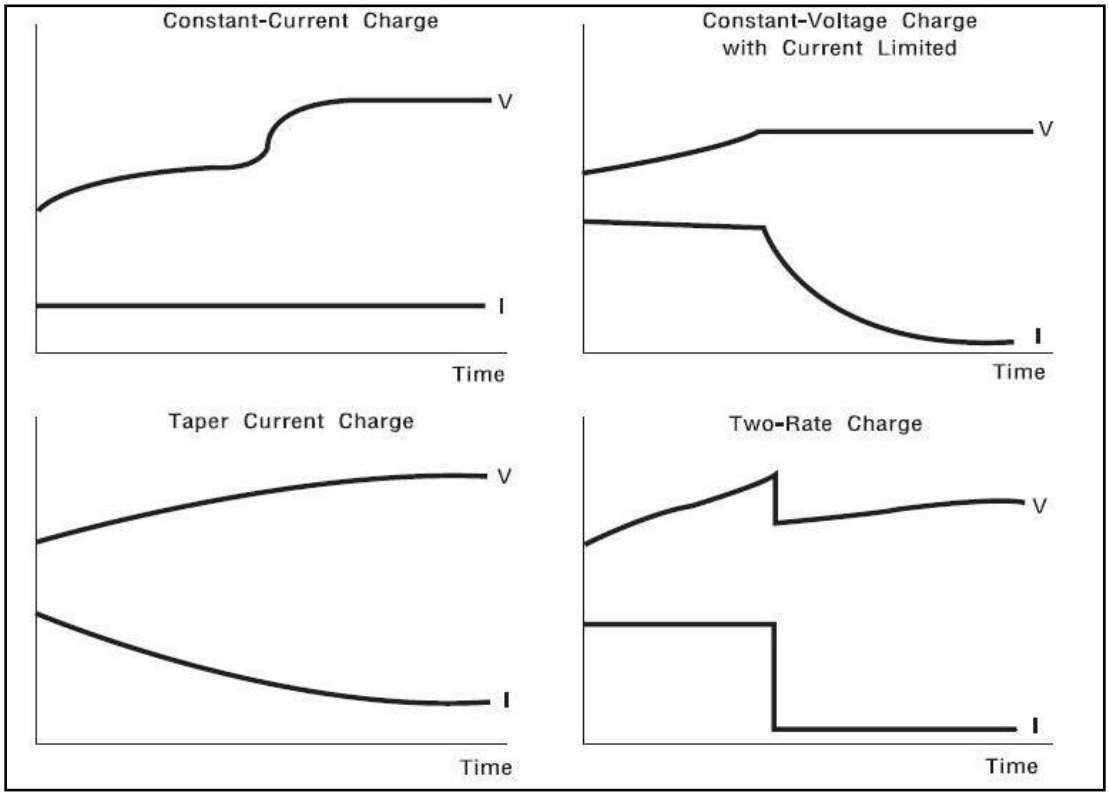

Figure 2.3 Different Types of Charging Methods [10]

2.2.5 Internal Voltage Control Charging

Internal voltage control charging methods is employs by controlling charging and discharging of the internal voltage of the battery instead of terminal voltage. The new methods has been discovered because the capacity of the battery is estimated by the potential differences between two electrodes of the battery, named external voltage and the battery has internal resistance that makes it difficult to control the charging and discharging process. Usually, when battery is being charge, the voltage increased and as it discharging, the voltage decrease. As the number of charging cycle increase, the discharge time of the battery becomes shorter [8]. This is caused by the increasing in internal resistance as the battery deteriorates causing the voltage of battery rapidly depletes to 10.5 V.

The objective of the internal voltage charging is to fully charge a battery by flowing sufficient current to it. It uses meter relays to control the charging and discharging process. The meter relay is connected to the battery and has been set to start charging when the battery voltage is 10.5 V and discharging when the voltage is 14.5 V [8]. This methods has been proved to prolong the battery life because as the battery is fully charge, no excess current can flow into the battery as the relays has switch to discharging state. The capacity of the battery can sufficiently utilized when the methods is used. Furthermore, this method proved to increase the effectiveness of the battery because the upper limit of charging batteries increases.

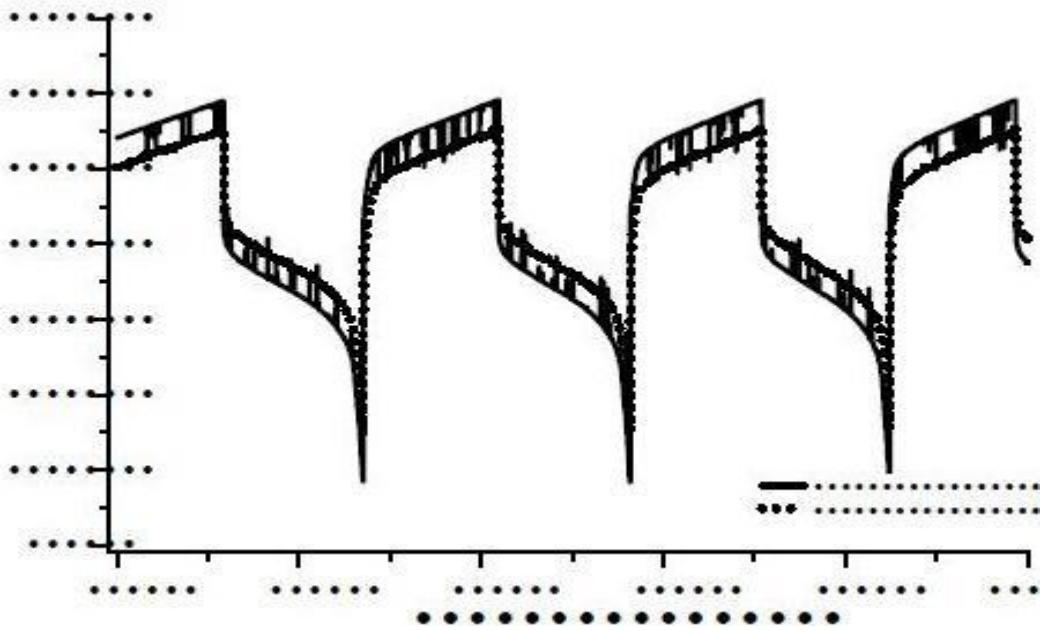

Figure 2.4 Time variation of the internal and external voltage of test battery [8]

2.2.6 High Current Pulse Charging

The principles of current pulse charging is by applying large currents into the battery at periodic intervals with a defined pulse width to reduce or avoid gassing and thus increase charge acceptance and efficiency. Research show that pulse charging method produce significant reductions in charging time and increase the battery cycle life [11]. Experimenting test show that when applied to specific battery and compared it to other conventional charging methods, it show improvements in charging time of an order magnitude and improvements in battery life by three to four times [9]. Current pulse charging uses a circuit that consists of mirco-controlled current source, synchronous rectifier, supervisory microprocessor and personal computer for interfacing. The designed circuit supply up to 100amp current pulses for charging or discharging of lead acid battery. It also provide constant charge and discharge currents but with much lesser value